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UPDATE of estimates of the Spawning Stock Biomass for sardine (*Sardina pilchardus,* W.) off the north Atlantic Spanish Coast in 2005 applying the DEPM

By

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1. Introduction

Following the recommendation of ICES WGACEGG Report 2006 (ICES, 2006) a review of the sardine parameter adult sampling during PELACUS 0405 Spanish surveys was presented. As result of this review a new estimation of sardine (*Sardina pilchardus)* Spawning Stock Biomass (SSB) n the north Atlantic Spanish coast was required.
During April 2005, the IEO (Instituto Español de Oceanografía) carried out two combined surveys one for ichthyoplankton on board R/V *Cornide de Saavedra* (SAREVA 0405) and another for adult surveying on board R/V *Thalassa* (PELACUS 0405), covering north Atlantic Spanish waters and the inner part of the Bay of Biscay. Month of April was chosen as it coincides with the highest sardine spawning intensity in the area of study.
The present paper provides the update of a previous estimation of 2005 sardine SSB off the Northern Coast of Spain (VIIIc and IXa (North) ICES Divisions) as result of an update of sardine adult parameter estimations.

2. Material and Methods

To estimate Spawning Stock Biomass (SSB), apart from the Total egg production (Po) and the spawning area, it is necessary to estimate the daily fecundity of adult sardines.
Table 1 summarises the different surveys contributing to sampling for the application of the DEPM during April 2005.

Ichthyoplankton survey

The ichthyoplankton survey (SAREVA 0405) was carried out on board R/V Cornide de Saavedra from 13th April to 3rd May. The area covered was the north-western Iberian Peninsula waters and the inner part of the Bay of Biscay (from 42°N to 44°N). A total of 375 stations were sampled with a PAIROVET net (Smith et al, 1985) (Fig. 1)
In laboratory, the PAIROVET samples were sorted again in order to remove any remaining eggs and then all sardine eggs were classified into 11 stages of development (Gamulin and Hure, 1955)

Estimation of the different DEPM parameters were carried out using different packages developed within the open source statistical software and computing language R (R, 2006). geofun, eggsplore and shachar R packages (Bernal et al ,2003) were used to analyse the data. Daily egg production (P_0) and mortality (z) rates were estimated by fitting an exponential model:

$$E[P] = P_0 \, e^{-Z \, age}$$

The estimate of daily egg production was obtained using generalised linear model with negative binomial distribution) and Bayesian ageing method, (Bernal,2001).

Adult parameters

The adult survey (PELACUS 0405) was carried out on board R/V Thalassa and a commercial purse seine chartered covering the North Atlantic Spanish waters. Overall samples were obtained from the shelf between 30-200 m. isobaths.
In each haul, a random sample of 50-100 sardines during the biological sampling was utilised for the estimation of the sex ratio (R), the spawning fraction (S) and female mean weight (W) parameters. Moreover hydrated females collected in overall survey were used to estimate batch fecundity (number of oocytes released per spawn, F).

3. Results

Estimation of Daily egg Production

A total of 123 CalVET stations of 375 sampled stations were positive for sardine eggs.

The total area sampled was calculated as the sum of the area represented by each station. The spawning area was delimited with (presence of sardine egg stations). A total sampling area of 41756 km^2 and a total spawning area of 13971 km^2 have been estimated (Figure 3).

The estimate of daily egg production was obtained both using an iterative estimation of mortality (generalised linear model with negative binomial distribution) and multinomial egg ages. A mortality estimation of -0.011 h^{-1} (CV= 42) and a daily egg production of 250.60 egg/m^2 (CV=21) have been estimated by this way.

Finally, the Total egg production (Po) is has been estimated in 3.50×10^{12} eggs/day (CV = 21).

This value is higher that estimation presented in 2006 ICES WGACEGG but could have been underestimated the total spawning area (10033 km2).

Estimation of adult parameters

For estimate the **Mean female weight** (W) was used data from 513 nonï hydrated females collected during the PELACUS 0405 survey

Mean female weight for the whole survey area was 83.77 g (CV=4%).

Sex ratio (R). A total of 1068 mature sardine from 30 samples were used for the estimation in the surveyed area. The sex ratio was 0.525 (CV =0.5%)

Spawning fraction (S) A total of 403 non-hydrated ovaries of sardine adult females were considered for the estimation of the spawning fraction
The estimated spawning fraction for the whole surveyed area was 0.153 (CV=10%).

To estimate **Batch fecundity** (F) a total of 112 females were used to estimate the batch fecundity..
To estimate Batch fecundity a GLM with Poisson error distribution was chosen. This model, explaining the 38% of the total variance

Mean batch fecundity for sardine in 2005 was estimated to be 34.386 (CV= 3%)

SSB estimates

The spawning biomass was computed according to:

$$SSB = \frac{P_0 * Area^+ * W}{F * S * R}$$

Stratification was not considered to estimate the spawning stock biomass due to be not found clear spatial differences between adult parameters. Then a unique stratum was considered. The estimated spawning biomass for the whole surveyed area (off North Atlantic Spanish coast) was 106.2 10^3 t with a CV of 47%.

Table 2 shows a summary table of estimated parameters for sardine in 2005.

4. Discussion

The 2005 SSB preliminary estimation presented in 2006 ICES WGACEGG (154.5 10^3 t) was the highest of the whole series. This high value of SSB was explained as result of the increase of Total egg production estimate and decrease spawning fraction estimate in relation to temporal series for sardine in north Atlantic Spanish Coast.
With the review of adult parameters for 2005, the spawning fraction estimate was a similar value in relation previous years. Moreover it was made a review of total egg production for 2005 and it was estimated a higher Total egg production in relation to estimation presented in 2006 WGACEGG (Table 4). This was due to en underestimation of Total spawning area.
The 2005 sardine spawning biomass estimate (106.2 10^3 t) is lower that previous estimation presented in 2006 ICES WGACEGG in 2002 (Table 3). This decrease of sardine Spawning Stock Biomass in relation with preliminary estimation should be due mainly to variation of the spawning fraction estimate and egg production estimate.

The 2005 sardine spawning biomass estimate (106.2 10^3 t) was higher that 2002 estimation SSB (50.7 10^3 t) and the highest value in the temporal series (Fig.4).
By other hand a light increase of CV in SSB estimation was obtained (47%) in relation sardine SSB estimation for 2002 (Table 3).

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Survey	Type	Vessel	Dates	Sampler	Total samples
SAREVA0405	Ichthyoplankton	R/V Cornide de Saavedra	13 Aprilï 3 May	CALVET	375
SAREVA0405	Ichthyoplankton	R/V Cornide de Saavedra	13 Aprilï 3 May	CUFES	379
PELACUS0505	Acoustic	R/V Thalassa	3 ï 30 April	Pelagic trawl	59
PELACUS0505	Adults	Commercial	3 ï 30 April	Purse seine	17

Table 1. Description of the ichthyoplankton and adult surveys

Parameter	Estimate	CV
Egg production (P_0)	$3.5x10^{12}$	21
Female weight (W)	83.8	4
Batch fecundity (F) 10^3	34.4	3
Spawning fraction (S)	0.153	10
Sex ratio (R)	0.525	1
Spawning biomass	$106.2 x10^3$	47

Table 2: DEPM 2005 estimates of the adult parameters and SSB in the total area with correspondent coefficient of variation.

Year	SSB
1997	20.7 (84)
1999	13.4 (77)
2002	50.7 (33)
2005	106.2 (47)

Table 3. Sardine Spawning Biomass (10^3 t) estimated by DEPM. Coefficient of Variation in brackets

Year	Parameter	GAL	W CANT	E CANT	Total
1997	Egg production				0.72 (82)
1999	Egg production				0.34 (44)
2002	Egg production	0	0.66 (32)	0.20 (31)	0.52 (33)
2005	Egg production				3.50 (21)
1997	Female weight				70.1 (6)
1999	Female weight				66.3 (41)
2002	Female weight	67.6 (11)	78.6 (8)	77.7 (6)	
2005	Female weight				83.8 (4)
1997	Batch fecundity				26.5 (5)
1999	Batch fecundity				21.8 (12)
2002	Batch fecundity	23.6 (13)	27.7 (8)	26.9 (6)	
2005	Batch fecundity				34.4 (3)
1997	Spawning fraction				0.18 (15)
1999	Spawning fraction				0.14 (26)
2002	Spawning fraction	0.243 (38)	0.075 (14)	0.125 (20)	
2005	Spawning fraction				0.153 (10)
1997	Sex ratio				0.52 (11)
1999	Sex ratio				0.55 (45)
2002	Sex ratio	0.519 (7)	0.604 (14)	0.494 (22)	
2005	Sex ratio				0.525 (1)

Table 4. DEPM parameter estimates for the sardine off the North Atlantic Spanish coast in period of1997-2005. Coefficient of variation are in brackets. GAL: Galician coast, WCANT: West Cantabrian coast, ECANT: East Cantabrian coast. Egg production: 10^{12} eggs day^{-1}, Female weight: g, Batch fecundity: 10^3 eggs

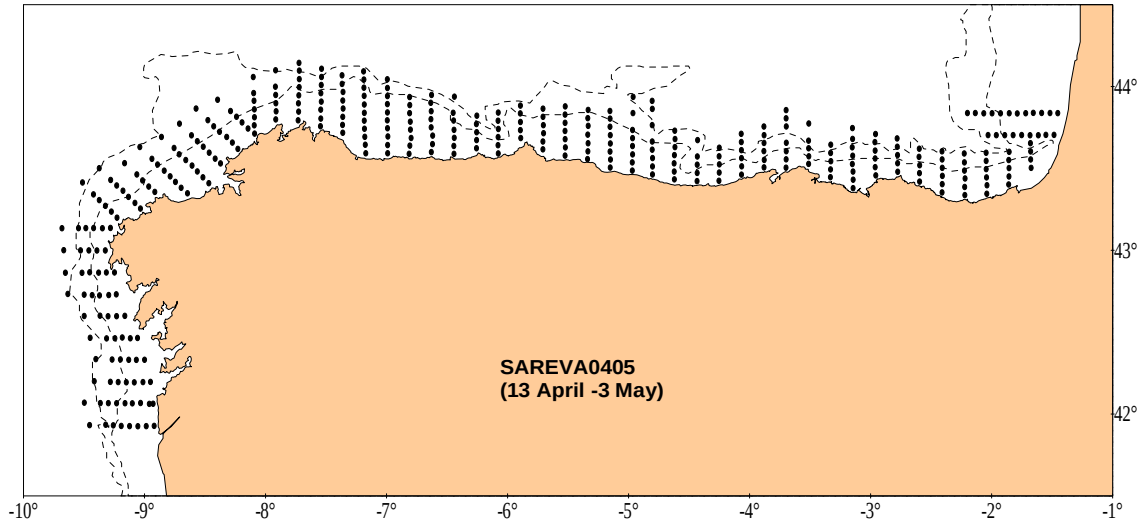

Figure 1. Location of PAIROVET stations in SAREVA0405

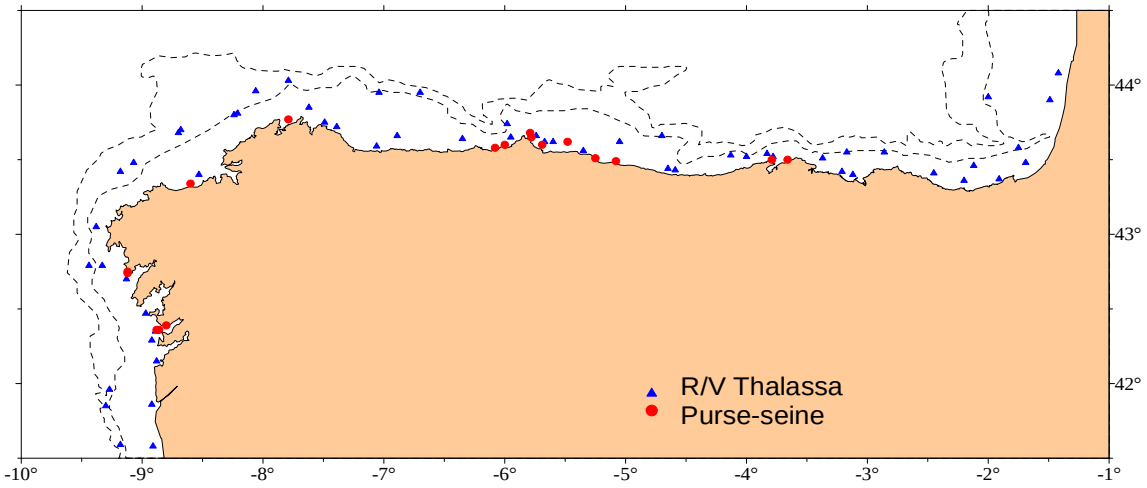

Figure2. Location of hauls during PELACUS 0405 survey.

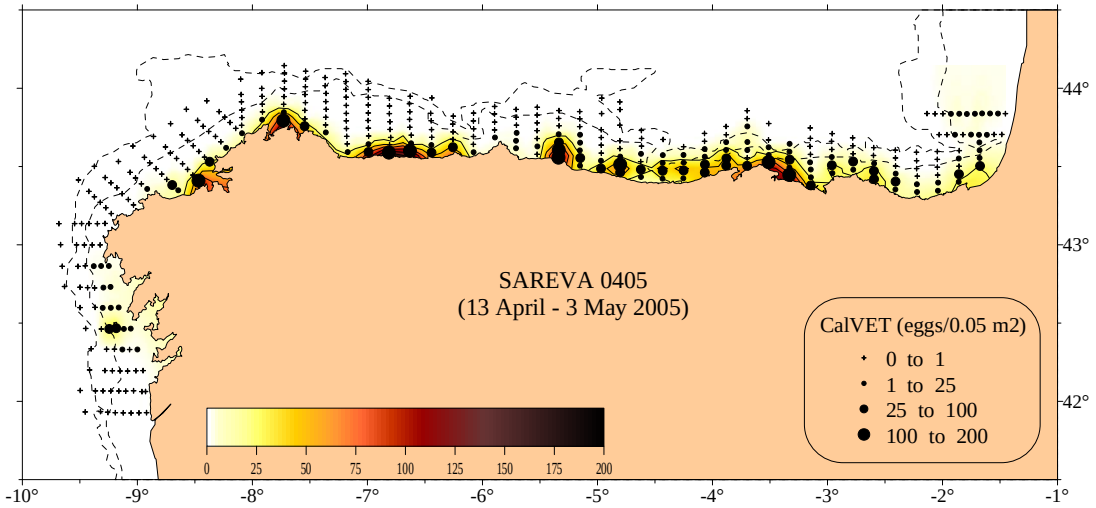

Figure 3. Sardine egg distribution and abundance. Size of circles are relative to egg abundance.

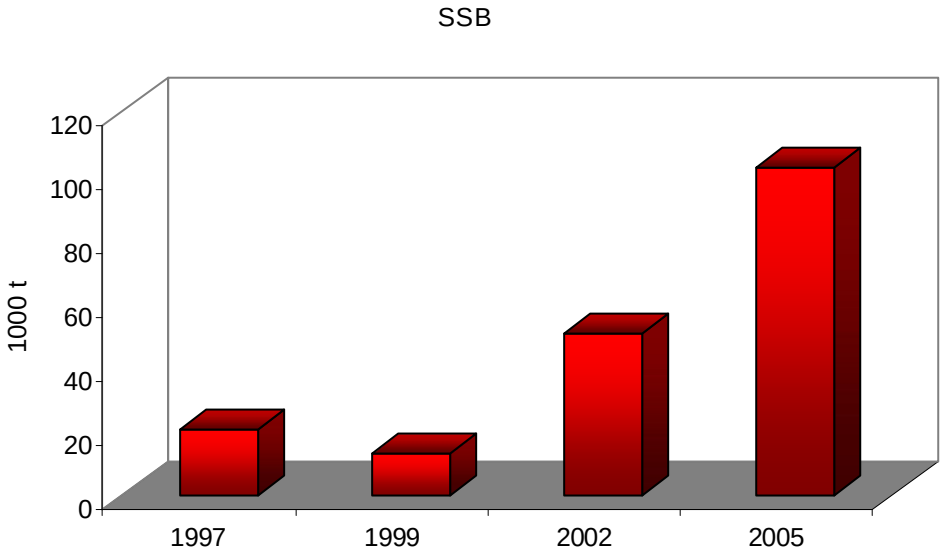

Figure 4 Series of biomass estimates (10^3 tonnes) of sardine off the north Atlantic Spanish Coast applying the DEPM since 1997.